The effect of the socioeconomic status on the measurement of asthma control

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ABSTRACT

Background: *The Asthma Control Test (ACT) is a commonly used scoring system for evaluation of asthma control in the pediatric and adult populations. Asthma control has been deemed poor in those economically disadvantaged.*

Objective: *To study whether the ACT is affected by socioeconomic status (SES) as evaluated by the percentage of the federal poverty level and the education level.*

Methods: *This was a cross-sectional study (N = 307), in which the patients were surveyed for demographics data and underwent ACT scoring, spirometry (forced expiratory volume in the first second of expiration) and fractional concentration of exhaled nitric oxide testing.*

Results: *There was a positive correlation of improved mean score on the ACT ($p < 0.001$) with higher education status and higher federal poverty level status.*

Conclusion: *SES plays a factor in the way patients perceived their asthma control, and therefore affected how they scored on the ACT.*

(Allergy Asthma Proc 43:e11–e16, 2022; doi: 10.2500/aap.2022.43.210103)

Asthma management is guided by quantifying patients' asthma control via parameters such as lung function (forced expiratory volume in the first second of expiration [FEV_1] and FEV_1 to forced vital capacity ratio), lung inflammation (fractional concentration of exhaled nitric oxide [FeNO]), and validated questionnaires (Asthma Therapy Assessment Questionnaire, Asthma Control Questionnaire, Asthma Control Test [ACT]) (QualityMetric, Johnston RI).[1,2] The ACT is a patient-based tool that aids health-care practitioners in quantifying asthma symptoms into categories: well controlled (score of 20 to 25), not well controlled (score of 16–19), and very poorly controlled (score of ≤15). The pediatric version of the ACT test poses seven questions with answers depicted as facial expressions that range from sad to happy. Results are categorized similarly as are the adult ACT scores. A change in score that is clinically significant, also known as the minimally important difference (MID), for the ACT is 3.

Objective parameters of monitoring asthma control include measuring a patient's FEV_1 and FeNO.[2,3] Components of well-controlled asthma include FEV_1 value of ≥80%, not well controlled is designated as a value of 60–80%, and very poorly controlled is a value of <60%. The American Thoracic Society guidelines[4] strongly recommend FeNO in monitoring airway inflammation in patients with asthma. Higher FeNO levels are a predictive factor for asthma exacerbations and declining lung function.[5,6] It has long been observed that asthma control is worse in those patients who come from an economically disadvantaged urban community. Although there is no clear causal link established between asthma and socioeconomic status (SES), the prevalence of poor control remains high in this group.[6–8] Our article aimed to study the effect of the SES by means of educational attainment and family income as a percentage of federal poverty level (PFPL) on the validity of the ACT, by comparing it with FEV_1 and FeNO values, and determining if changes are congruent. We hypothesize that the ACT will be incongruent with objective parameters.

METHODS

Ethics

The study was approved by the institutional review board (protocol 2014–139) at Medstar Health Research, Baltimore, Maryland. Oral informed consent was required for all the adults. For patients ages < 18 years, both consent of a guardian and assent of the minor were required.

Study Population and Setting

Patient recruitment and data collection occurred over a 2-year period starting in 2015 at the outpatient offices of the Asthma, Allergy and Sinus Center (Rockville, Union

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The authors have no conflicts of interest to declare pertaining to this article

No external funding sources reported

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Memorial Hospital, Waldorf, and White Marsh). Three hundred and seven patients were selected based on a previous diagnosis of asthma, ages ranged from 4 to 80 years. Of the 307 patients, 286 were included in the study and 21 were excluded due to having either incomplete questionnaires or incomplete physiologic testing data (FeNO, FEV_1). Of the 286 patients, FeNO data were available for 229 patients.

Study Design

This study was a cross-sectional review and survey. Patients with a previous diagnosis of asthma were offered participation through an informed consent process. On arrival, the patients completed the ACT and spirometry testing, which included prebronchodilator FEV_1 values. For this article, we designated patients' FEV_1 value of ≥80% as well controlled and those with an FEV_1 value of ≤80% as poorly controlled. When possible, the FeNO was also measured. The pediatric ACT forms were filled by pediatric patients between ages 4 and 11 years and by their parents. The adult ACT form was administered to patients ages > 11 years. Adult patients and parents of the pediatric patients were given a demographics questionnaire (Table 1), which included family income as a percentage of the federal poverty level (PFPL), and the education level of the adult patient or the parent of the child with asthma.

To quantify PFPL (Table 2), any income level of ≤100% was denoted as "100%," any income level of ≤200% was denoted as "200%," any income level of ≤300% was denoted as "300%," and any income level of >300% was denoted as "400%." Education attained at the high school level or lower was denoted as "HS," college experience without attainment of a bachelor's degree was denoted as "CE," and attainment of a bachelor's degree or higher was denoted as "CD." FEV_1 (N = 307) and FeNO (n = 229) values were used as objective measures. Statistical analysis was conducted for education level, and PFPL within the well-controlled and poorly controlled categories. Similarly, adults with an FeNO value of ≤25 ppb and children ages < 12 years with an FeNO value ≤ 20 ppb were the well-controlled group. Adults and children ages < 12 years and with an FeNO value of >25 ppb were the poorly controlled group. Similar statistical analysis was repeated for these groups.

Table 1 **Demographics and baseline characteristics of the study participants (n = 286), with the exception of FeNO (n = 229)***

	No. Patients	Total Study Population, %
Age		
4–17 y	117	41
18–64 y	139	49
≥65 y	30	10
Gender		
Female	109	38
Male	177	62
Ethnicity		
African American	133	47
Hispanics	8	3
White	104	36
Other	41	14
Highest education level		
College degree or higher	78	27
Some college education	93	33
High school diploma or lower	115	40
Annual household income as a PFPL		
100%	50	18
200%	66	24
300%	38	14
400%	117	43
Spirometry, FEV_1		
≥80%	156	55
<80%	130	45
FeNO (n = 229)		
Low	157	69
High	72	31

FeNO = Fractional concentration of exhaled nitric oxide; PFPL = percentage of the federal poverty level; FEV_1 = forced expiratory volume in the first second of expiration.
**Low FeNO encompasses adults with FeNO values of ≤25 ppb and children ages < 12 y with FeNO values of ≤20 ppb; high FeNO encompasses adults with FeNO values of >25 ppb and children ages < 12 y with FeNO values of >20 ppb.*

Statistical Analysis

A multiple linear regression model was created with education and PFPL as dependent variables (defined in Table 3). ACT scores were compared with each variable that had shown a statistical significance in the model individually. Bivariate analysis was conducted by using the two-sample t-test and analysis of variance (ANOVA). *Post hoc* comparisons between groups were conducted if ANOVA results were significant. The p value in the *post hoc* comparison was adjusted for multiple comparisons by using the Bonferroni method. Stratified bivariate analysis was also conducted stratified by FEV_1 values of <80% and FEV_1 value of ≥80%, and by low FeNO and high FeNO values. Statistical significance was achieved at $p < 0.05$. The software used for statistical analysis was RStudio, version 1.0.143 (RStudio Inc, Boston, MA).

RESULTS

Baseline characteristics for all the study participants are given in Table 1. A total of 307 patients were

Table 2 **Annual household income and PFPL for the 48 contiguous states and Washington, D.C.***

Family Size	PFPL 100%	200%	300%	400%
1	$11,770	$23,540	$35,310	$47,080
2	$15,930	$31,860	$47,790	$63,720
3	$20,090	$40,180	$60,270	$80,360
4	$24,250	$48,500	$72,750	$97,000
5	$28,410	$56,820	$85,230	$113,640
6	$32,570	$65,140	$97,710	$130,280
7	$36,730	$73,460	$110,190	$146,920
8	$40,890	$81,780	$122,670	$163,560

PFPL = Percentage of federal poverty level.
**Adapted from Ref. 11.*

Table 3 **Multiple linear regression model of the adjusted effect of the education level and PFPL on ACT score compared with a base reference value**

Variable	Estimate	95% CI	*p*
Intercept	18.6	17.2–20.0	<0.001
Education level			
HS		Reference	
CE	0.9	–0.4 to 2.3	0.17
CD	2.4	1.1–3.7	<0.001
PFPL			
100%		Reference	
200%	1.8	0.2–3.4	0.032
300%	2.8	1.2–4.5	<0.001
400%	2.5	1.0–4.0	0.001

PFPL = Percentage of the federal poverty level; ACT = Asthma Control Test; CI = confidence interval; HS = high school diploma or lower, CE = some college education, CD = college degree or higher.

enrolled, and, of these, 286 had complete demographic data. For the education levels, 78 (27%) were in the HS group, 93 (33%) were in the CE group, and 115 (40%) were in the CD group. For PFPL, 50 patients (17%) were in the 100% group, 66 (23%) were in the 200% group, 56 (20%) were in the 300% group, and 114 (40%) were in the 400% group. Of these, 156 patients (55%) were well controlled, with an FEV_1 value of ≥80%. FeNO values were reported on 229 patients, of whom 157 (69%) had low values (Table 1).

The multiple linear regression model (Table 3) isolates the effect that a single factor has on the ACT score while holding all other factors constant. For each subgroup (education level and PFPL), one variable was designated as the reference and used as a comparison metric within the groupings. A significant increase of 2.4 ($p < 0.001$) was found when comparing patients in the CD group with those in the HS group. There was no significant change between the HS and CE groups. When comparing the other PFPL groups with those in the 100% group, a significant increase was seen: 1.8 ($p = 0.032$) for the 200% group, 2.8 ($p < 0.001$) for the 300% group, and 2.5 ($p = 0.001$) for the 400% group.

Analysis of the Education Level

An ANOVA test performed on the education-level groups indicated a statistically significant difference between the mean ACT scores ($p < 0.001$) among the three cohorts of HS, CE, and CD (Fig. 1*A*). The *post hoc* analysis indicated a significant score increase of 2.4 ($p = 0.002$) when comparing the CE group with the HS group, with a corresponding score increase of 3.7 ($p < 0.001$) when comparing the CD group with the HS group. There was no significant score increase when comparing the CE group with the CD group.

When using FEV_1, the <80% group showed a statistically significant difference between the mean ACT scores for the different education groups ($p < 0.001$) (Fig. 1*B*). There was a significant MID increase of 3.2 ($p = 0.004$) when comparing the CE group with the HS group, and a significant MID of 4.4 ($p < 0.001$) when comparing the CD group with the HS group (Fig. 1*B*). There was a statistically insignificant change in the score when comparing the CE group with the CD group; however, the ACT score crossed the threshold of 20, a clinically significant change in management. The FEV_1 well-controlled group also indicated a statistically significant difference between the mean scores for different education groups. The change in ACT score from the HS group to the CD group was 3 ($p < 0.001$). When comparing the HS group with the CE group, there was a clinically significant change from the poorly controlled to the well-controlled category but no clinically significant change when comparing the CE group with the CD group. A *post hoc* analysis indicated a significant MID of 3.0 ($p < 0.003$) when comparing the CD group with the HS group.

When using FeNO, the poorly controlled group indicated a statistically significant difference between the mean scores for the different education groups ($p = 0.02$) (Fig. 1*C*). There was a score of 5.0 ($p = 0.02$) when comparing the HS group with the CD group. When comparing the HS group with the CE group, there was a score of 3.9; however, it marginally did not cross the threshold of 20. When comparing the CE group with the CD group, the change in score was 1.1. The FeNO well-controlled group also showed a statistically significant difference between the mean scores for the different education groups ($p < 0.001$). When comparing the HS group with the CD group, there was an increase of 3.3 ($p < 0.001$). When comparing the HS

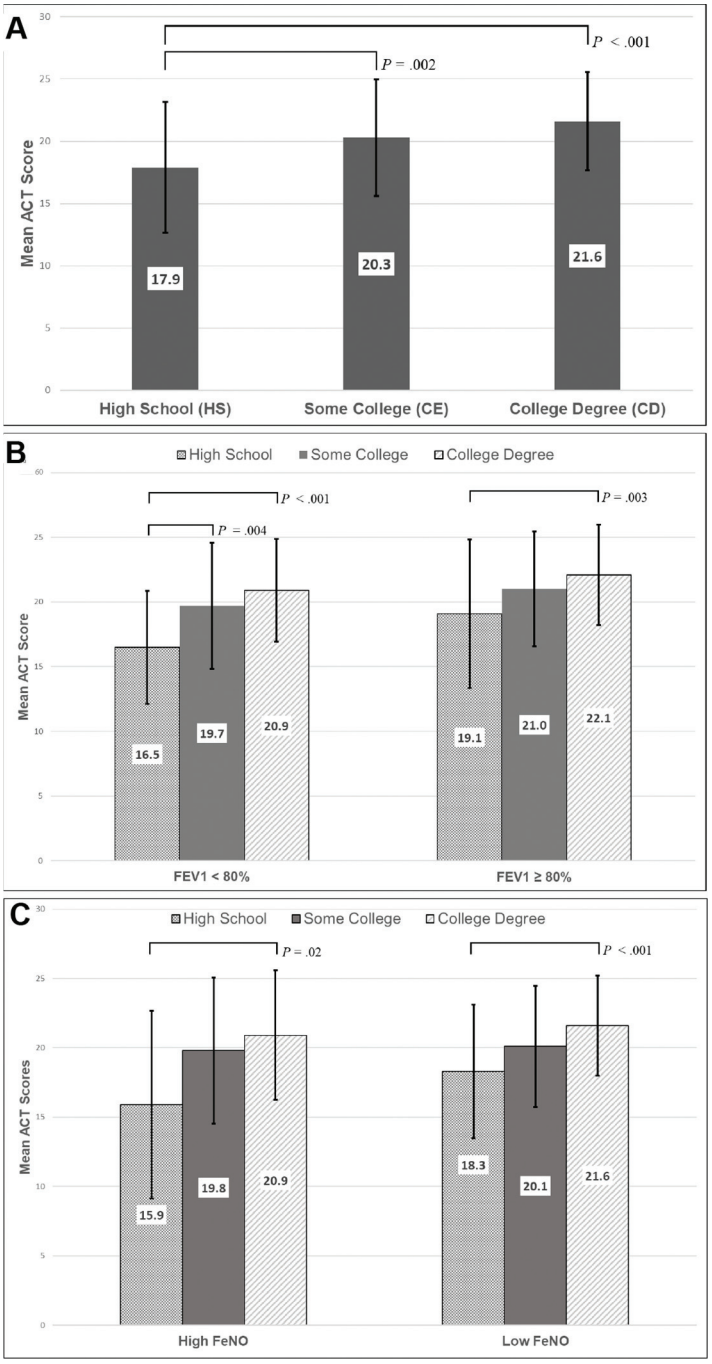

Figure 1. *(A) The mean ± SD ACT scores of the patients with asthma and with varying education levels as stratified into the cohorts. (B) The mean ± SD ACT scores for the patients with asthma and of varying education levels as grouped by FEV_1 values of <80% and FEV_1 values of ≥80% subgroups; data were analyzed with ANOVA testing. (C) The mean ± SD ACT scores for the patients with asthma and of varying education levels (high school, some college, college degree) as grouped by a low FeNO value (≤25 ppb) and a high FeNO value (>25 ppb); data were analyzed with ANOVA testing. Correlate with line over bar indicates the comparison groups, and statistical significance is stated as p value. SD = Standard deviation; ACT = Asthma Control Test; FEV_1 = forced expiratory volume in the first second of expiration; ANOVA = analysis of variance; FeNO = fractional concentration of exhaled nitric oxide.*

group with the CE group, the mean ACT scores crossed the threshold of not well controlled and well controlled; however, the change in score was 1.8. When comparing the CE group with the CD group, there was no clinically significant change in score.

Analysis of PFPL

ANOVA testing performed on the PFPL groups indicated a statistically significant difference between the mean scores ($p < 0.001$) (Fig. 2 *A*). The *post hoc* analysis indicated a significant mean score increase of 3.4 ($p < 0.001$) when comparing the 100% group with the 200% group, a significant increase of 3.9 ($p < 0.001$) when comparing the 100% group with the 300% group, and a significant increase of 4.4 ($p < 0.001$) was noted when comparing the 100% group with the 400% group.

When using FEV_1 (Fig. 1*B*), the poorly controlled group (FEV_1 < 80%) showed a statistically significant difference between the mean scores for the different PFPL groups ($p < 0.01$). There was a significant mean score increase of 3.1 ($p = 0.04$) when comparing the

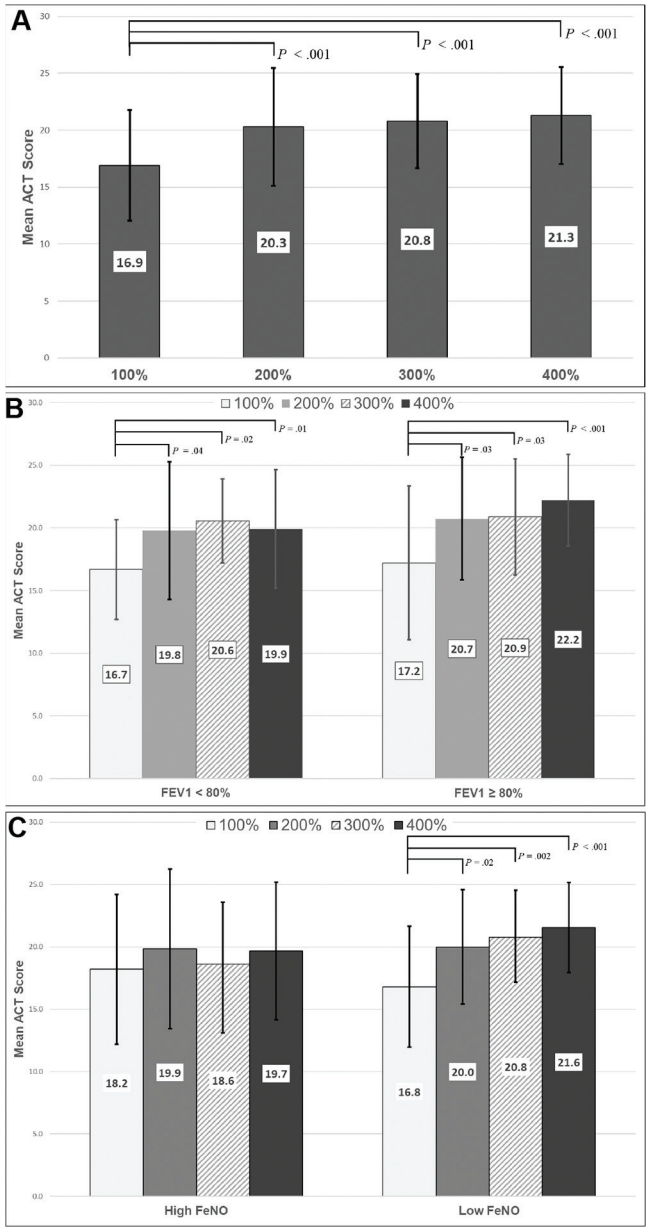

Figure 2. *(A) The mean ± SD ACT scores of the patients with asthma and with varying PFPLs as stratified into the cohorts. (B) The mean ± SD ACT scores for the patients with asthma and with varying PFPL levels, as grouped by FEV_1 values of <80% and FEV_1 values of ≥80% subgroups. Data were analyzed with ANOVA testing. (C) The mean ± SD ACT scores for the patients with asthma of varying PFPL levels as grouped into low FeNO and high FeNO values. Data were analyzed with ANOVA testing. Correlate with line over bar indicates comparison groups, and statistical significance is stated as p value. SD = Standard deviation; ACT = Asthma Control Test; PFPL = percentage of federal poverty level; FEV_1 = forced expiratory volume in the first second of expiration; ANOVA = analysis of variance; FeNO = fractional concentration of exhaled nitric oxide.*

100% group with the 200% group, a significant increase of 3.9 ($p = 0.02$) when comparing the 100% group with the 300% group, and a significant increase of 3.3 ($p = 0.01$) when comparing the 100% group with the 400% group. The well-controlled group (FEV_1 ≥80%) also showed a significant difference between the mean scores for the different PFPL groups ($p < 0.001$). There was a significant mean score increase of 3.5 ($p = 0.03$) when comparing the 100% group with the 200% group, a significant increase of 3.7 ($p = 0.03$) when comparing the 100% group with the 300% group, and a significant increase of 5.0 ($p < 0.001$) when comparing the 100% group with the 400% group. Only the 100% group had a statistically significant difference in the mean ACT score when compared with the other groups. The comparison among the 200%, 300%, and 400% levels yielded no significant relationships.

When using FeNO, the poorly controlled group showed no statistically significant difference between the mean scores for the different PFPL groups ($p = 0.8$). However, the well-controlled group indicated a statistically significant difference between mean scores for the different PFPL groups ($p < 0.001$). The *post hoc* analysis indicated a significant increase of 3.1 ($p = 0.02$) when comparing the 100% group with the 200% group, a significant increase of 4.0 ($p = 0.002$) when comparing the 100% group with the 300% group, and a significant increase of 4.7 ($p < 0.001$) when comparing the 100% group with the 400% group.

DISCUSSION

Income and education level provide two separate and nonequivalent means to evaluate the overall effect of SES on ACT scoring.[9] In the bivariate analysis of the education level, there was a statistically significant trend that patients with lower education levels had lower ACT scores; however, only the difference in mean ACT scores between the HS and CD groups exceeded the MID. After splitting the sample based on the FEV_1 score and the FeNO score, it became evident that the same trends were present in the subgroup, despite the FEV_1 or FeNO measure of control.

Similarly, in the bivariate analysis of the PFPL, the 100% group had a statistically significant difference in the mean ACT score compared with the other groups and each exceeded the MID. After splitting the sample based on the FEV_1 score, the same trend emerged in the group with objectively well-controlled asthma. This trend was also seen with the FeNO values, although not at a statistically significant level. The absence of statistical significance may be due to the smaller group of patients who performed FeNO tests (n = 229). Clinically, this indicated that the patients

who fell within the 100% range of the PFPL described their asthma as worse on the ACT as reflected by a statistically significant lower score, especially in comparison with those at higher income levels; however, this difference was not apparent when studying SES and FEV_1 or FeNO outcomes. Essentially, analysis of our data suggested that, when comparing a patient with an income at 300% PFPL and a college degree with a patient at 100% PFPL who did not graduate from high school, the second patient will have a clinically significant lower ACT score relative to the first patient.

SES has a high impact on disease morbidity and mortality, largely in part due to important factors such as access to health care, general attitude toward health, and environmental exposures.[10] However, we question if there was a discrepancy in the inherent nature of the ACT. Because the ACT is a self-administered patient tool, are those with lower educational attainment correctly completing and understanding the questions in the ACT? Could controlling for administration of the test by a health-care practitioner change the outcome of the score and thus change the course of management? We recommend that objective measures such as office-based spirometry and FeNO be incorporated when deciding to escalate management in patients with asthma from a lower SES based on ACT scores.

Limitations

This study did not incorporate a specialist's assessment as the ultimate determinant of asthma control. In addition, scoring in the pediatric population may be subject to errors because those patients may have identified their own education level instead of their parents. We also asked the pediatric patients to complete their own pediatric ACT forms as independently as possible, but, with patients as young as 4 years old, it is expected that the scoring may not be entirely reflective of their status. In addition, the study was powered to study a two-point cutoff of FEV_1 and FeNO, which indicated well controlled and not well controlled. Future studies should study this differentiation with a three-point cutoff, which includes well-controlled, moderately controlled, and poorly controlled asthma.

CONCLUSION

Patients of a lower SES have disadvantages in their health care with reasons that included affordability of care, personal values, and understanding of their disease. Those from a lower SES have lower average ACT scores, which may not reflect their true disease state, as demonstrated by incongruent FEV_1 and FeNO scores. One of the proposed confounders for this discrepancy is whether the patient's educational status influences his or her understanding of the questionnaire. As a result, the ACT may not be a good tool to study asthma control in those of a lower SES, and objective tests (FEV_1, FeNO) should be measured. We propose that future studies are required to study if there are differences in self-administered or health-care practitioner administered ACT scores among different SES groups, which eradicates the effect of SES on the discrepancy among FEV_1, FeNO, and ACT scores.

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